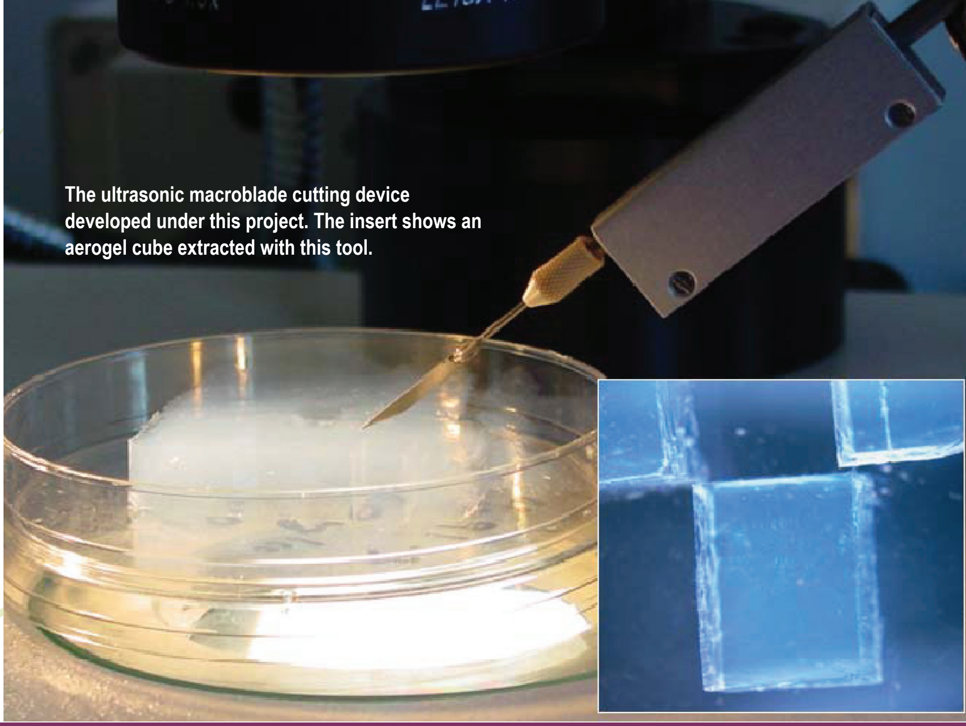
An LDRD Success Story



The ultrasonic macroblade cutting device developed under this project. The insert shows an aerogel cube extracted with this tool.

University of California
Lawrence Livermore National Laboratory

Stardust: From the Origins of the Solar System to Stockpile Stewardship

With LDRD support, LLNL's Stardust team is sampling and analyzing the building blocks of the Solar System by developing the capabilities to capture cometary and interstellar dust particles in aerogel, extract those particles, and determine the particles' makeup.

Achievements and Discoveries

- Tools developed at LLNL with LDRD funding enabled the successful extraction of samples from the return capsule, which landed in the Utah desert on January 15, 2006.
- Samples were analyzed and found to contain materials which have not been remotely detected in a comet, including calcium–aluminum inclusions (CAIs). Because CAIs solidify at several thousand degrees, their presence:
  - Suggests they formed close to the young Sun and then were flung outward, meaning much more mixing occurred in the early Solar System than was previously thought.
  - Lends credence to theories such as the "X-wind" theory, in which the materials that eventually condensed into our Solar System were propelled away from the young Sun by its strong magnetic field.
  - Indicates that we must re-examine our theories of flow and mixing in the early Solar nebula.

Relevance to LLNL Missions

- The extraction techniques being developed apply to fusion-class laser experiments seeking to recover, from aerogel, particulate ejecta generated during laser shots.
- The Stardust team's integrated analysis approach has application to the interrogation of nuclear materials in forensic studies supporting national security objectives.

About Stardust

- The "big picture" questions that LDRD helped the Stardust project answer include:
  - Were comets a source of Earth's water and the organic materials essential to life?
  - How did the Sun and planets actually form from the presolar cloud of gas and dust that also gave rise to comets like Wild 2?
- Stardust, the first U.S. solid-matter sample return mission since Apollo 17 in 1973, returned the first materials ever collected from a known comet.
- Wild 2 presented a rare opportunity—the chance to study an object that has remained relatively unchanged since it was formed during the early years of our Solar System billions of years ago. Thus, Wild 2 samples are a time capsule containing material from the Solar System when it first formed.
- Extraction and analysis technology developed in the Stardust project is crucial for obtaining the maximum information possible from the relatively small amounts of materials that such next-generation missions will bring back to Earth.
- Stardust is a model for future Discovery space missions to recover small quantities of samples from extraterrestrial bodies.

About LDRD

The Laboratory Directed Research and Development (LDRD) Program is LLNL's primary mechanism for funding cutting-edge R&D to enhance the Laboratory's scientific vitality. Established by Congress in 1991, LDRD collects funds from sponsored research and competitively awards those funds to high-risk, potentially high-payoff projects aligned with Laboratory missions.


LLNL's Stardust team.

Capabilities Developed by LDRD

LDRD has made possible the following Stardust-related achievements either with direct funding or indirectly—by helping develop capabilities, hire personnel, and establish track records in these areas.

- Critical technical know-how for manufacturing optimal aerogel for the Stardust mission
- State-of-the-art extraction technology for hypervelocity impact debris recovery:

  Ultrasonic-oscillation diamond microblades and steel macroblades

  Recovery of impact tracks and cometary debris from aerogel

  High-precision focused ion beam (FIB) milling and microneedles for recovery of cometary debris in metal foils and aerogel
- Analysis technology to characterize the materials' mineralogical, chemical, and isotopic composition:

  Nanoscale secondary ion mass spectrometry (NanoSIMS) for isotopic composition and mapping

  Scanning transmission electron microscopy (SuperSTEM) for mineralogy and major element chemistry

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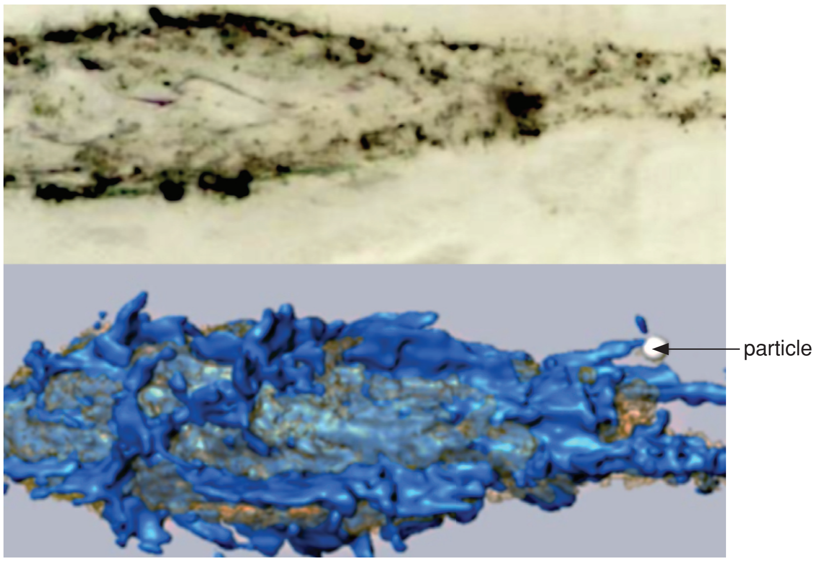
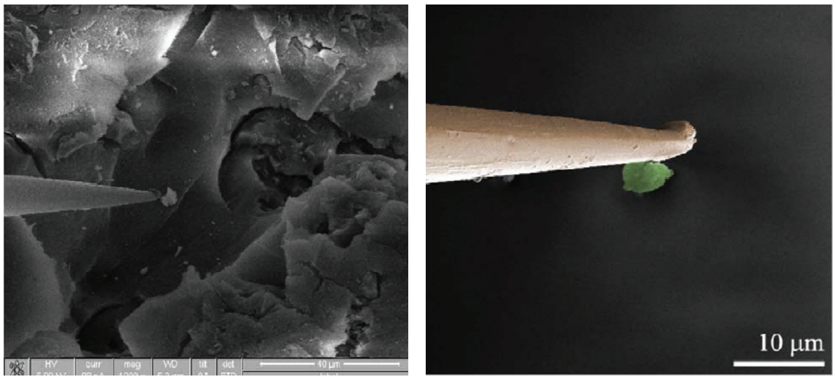


Optical micrograph (top) and volume rendered 3D representation (bottom) of the x-ray tomographic reconstruction of a cometary particle impact track.



The extraction of a particle from aerogel using the in situ micromanipulator fitted inside the focused ion beam chamber.